

FABRICATION OF GENESIS SAMPLE SIMULANTS USING PLASMA SOURCE ION IMPLANTATION (PSII)

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The Genesis mission addresses questions about the materials and processes involved in the origins of the solar system by providing precise knowledge of solar isotopic and elemental compositions, a cornerstone data set around which theories for materials, processes, events and time scales in the solar nebula are built, and from which theories about the evolution of planets begin. Genesis measures solar composition by collecting solar wind implanted in various passive collector materials for analysis in terrestrial laboratories. Genesis has also implemented an active concentrator target important for the analysis of oxygen isotopes in the solar wind.

Benefits to the Genesis Community

The main benefit of using PSII to fabricate Genesis sample simulants is that the samples will be very similar to those to be returned by the Genesis mission in 2004. These samples are needed by investigators to validate and improve sample preparation and analysis techniques such as secondary ion mass spectroscopy (SIMS), gas source mass spectrometry (GSMS), resonance ionization mass spectrometry (RIMS), and radiochemical neutron activation analysis (RNAA) [7]. Other techniques such as atom probe field ion-microscopy [8] may be uniquely capable of measuring the depth profiles of implanted solar wind species and will require simulants to develop methods for sample preparation and calibration.

Implanted Solar Wind Depth Profiles

Implanted Solar Wind Depth Profiles: Solar wind ions have ranges in materials on the order of 10 to a few hundred nanometers. In the case of 4He⁺ in minerals, the mean range is about 25 nm [1]. While secondary ion mass spectroscopy (SIMS) and step-wise heating provide valuable data on total elemental abundances and isotopic ratios, depth profiles are needed to characterize elemental and isotopic fractionations, a scientific goal of Genesis. Depth profiles at the scale of tens of nanometers are extremely difficult to measure at present and are typically simulated using the code, the Stopping and Range of Ions in Matter (SRIM) [1]. Radiation damage and diffusion effects complicate the interpretation of depth profile.

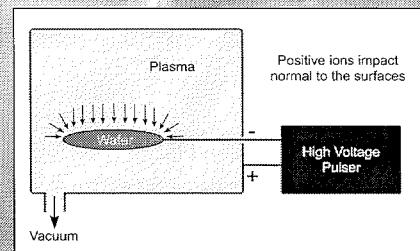


Figure 1: Schematic diagram of the Plasma Source Ion Implantation (PSII) process.

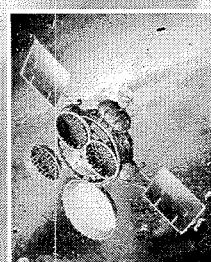
Solar Wind Simulation Using Plasma Source Ion Implantation (PSII)

It is desirable to test new analysis techniques for Genesis using standard samples that can be fabricated in the laboratory. Linear particle accelerators cannot efficiently perform low energy implantations of light elements such as those found in the solar wind, and require focusing using magnetic fields that can cause the ions to be implanted non-normal to the surface. Plasma source ion implantation (PSII) is capable of implanting species of solar wind energies (approx. 1 kV/q/amu) normal to the sample surface [2].

Plasma source ion implantation (PSII) is a non-line of sight technique for the surface modification of materials [3]. The target is placed in a 1 m³ chamber evacuated to a base pressure of about 10⁻⁵ torr. Gas of the species to be implanted is allowed to flow through the chamber at a pressure of several millitorr. A plasma is generated using tungsten filaments to ionize the gas by energetic primary electron impact. Other ways of generating a plasma for higher energy implantations include radiofrequency (RF) and glow discharge methods.

Negative high voltage pulses are applied to the target wafer, and the resulting electric field accelerates the ions in the plasma to high energies normal to the surface of the target (Figure 1) [4]. In the case of a wafer, significant asymmetries can occur at the edges where the electric field is changing rapidly.

Harris-Kuhlman (1998) demonstrated that PSII can be used to simulate the implantation of hydrogen and helium isotopes into terrestrial minerals with results similar to those from the Apollo 11 regolith samples (Figure 2) [2,5,6].



Artist's conception of the deployed Genesis payload [7].

Simulant Fabrication Approach

Sample wafers identical to the particle collectors on Genesis will be produced and prepared at JPL with the same coatings as the flight collectors. These wafers will then be implanted with the various elemental and isotopic ratios found in the solar wind with energies of 1 kV/q/amu using PSII at the University of Wisconsin - Madison. The total fluences of these implantations will be the same as those expected during the various phases of the Genesis mission [7]. Isotopes of the noble gases and other elements such as Li, B, C, N, O, Mg, Si, S, and Fe will be implanted according to measured isotope ratios and fluxes measured by the Apollo 16 Solar wind composition (SWC) experiment [9], and the Ulysses, WIND and SOHO spacecraft. The Genesis concentrator target will be simulated with and without hydrogen and helium to demonstrate the effect of enhanced fluences due to the concentrator. Finally, higher energy particles will be implanted to simulate solar flare interactions with Genesis. The high energy implantations can be tailored to match the fluence and energy spectra of the flares based on the measurements from the Genesis solar wind monitor which measures the density, velocity, temperature, and anisotropy of the protons and alpha particles as a function of time. The samples will then be divided and made available to the Genesis investigator and the international scientific community for use in developing and refining sample preparation and analysis techniques.

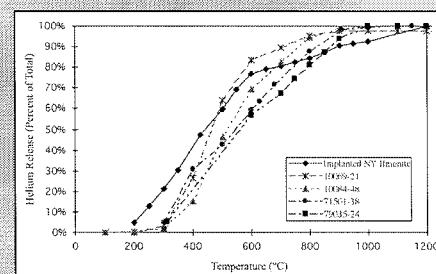


Figure 2: Release data of helium from the implanted New York ilmenite and samples of rocks and regolith from Apollo 11 (S) and Apollo 17 (E). Annealing steps of 50°C and 30 minutes were used for the implanted terrestrial sample while steps of approximately 100°C and 1 hour were used for the Apollo samples.

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References: [1] J. C. Neiger (2001) "The Stopping and Range of Ions in Matter" <http://www.srim.org>; [2] Harris-Kuhlman, K. R. (1978) Trapping and Diffusion of Helium in Lunar Ilmenite, Ph.D. Thesis, University of Wisconsin - Madison; [3] Conrad, J. et al. (1990) J. Vac. Sci. Tech. A, 8, 3142; [4] Koir, S. M. (1979) Per. Comm., [5] Peppin, P.O. et al. (1970) Proc. of the Apollo 11 Lunar Sci. Conf. 1435-1454; [6] Rick, U. et al. (1998) LPSC XVIII, 87-120; [7] Genesis Scientific and Technical Web Page, <http://www.gicx.jstec.ed.jp/genesis/>; [8] Kuhlman, K. R. et al. (2001) Ultramicroscopy, 89(1-3), 181-197; [9] Glass, J. et al. (1972) Apollo 16 Preliminary Science Report, NASA SP-312, 14-1 to 14-10.

The background image is a composite image containing Extreme Ultraviolet Imaging Telescope (EIT) images from three wavelengths (171, 195 and 284 angstrom) into one that reveals solar features unique to each wavelength. Since the Sun images come from the ground, it is black and white; they are color-coded for easy identification. For this image, the three simultaneous images from May, 1998 were each given a color code (red, yellow, green/blue) and overlaid onto one another.

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